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Development of Greenhouse solar Tunnel dryer for Industrial Fish drying of Selected species from the Western coastal region of India

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Abstract

The paper is aimed to develop a greenhouse type solar tunnel dryer for industrial drying of selected species of fish Croaker, Anchovy and Ribbon in the western coastal town Veraval (20° 53' N, 73° 26' E.), Gujarat, India and was installed at Jose and Brothers Fish Industry. The single span arc type G.I pipe frames were used to construct the dryer (collector area of 150.9 m^2) and covered with a single layer 200μ thick UVS polyethylene sheet. The performance of the dryer was evaluated as per a CRD statistical analysis using the drying parameters like pre-treatment with salt and without salt in the temperature range of T_1 (40-45) and T_2 (45-49). The test results showed that developed dryer can reduce moisture content of salt treated fish up to 42.85% to 66.66 % (db) between 8 to 16 h, whereas in case of unsalted fish moisture content was reduced up to 17.64 % - 25 % (db) in 24 to 32 hours of drying depending on a variety of fish and initial moisture content. The quality analysis showed that fish drying is better in the low temperature range.

Keywords: Solar tunnel dryer, fish, fish drying, pretreatment.

Introduction

Fish is an important food commodity and has been accepted as a source of quality protein[1], supplying almost 6% of the global protein requirement and 16% of the total animal protein[2]. Fish is a highly perishable by nature having short span of shelf life. In India, the fisheries sector is a provider of livelihood to almost seven million fishers, prime mover of costal economy and major foreign exchange earner with about 8000 km coastline apart from inland water resources[3] but the poor and insufficient methods of cold storage and improper postharvest practices accounts around 20% waste of fish[4]. In year 2012, marine fish landing was all time high about 3.94 million metric tons[5]. Gujarat has about 1600 km long coastline and offers large opportunities for the development of the fisheries sector with the major commercial catch on the Gujarat coast are Pomfret, Jew fish, Bombay duck, Prawn, Lobster, Ribbon, Shrimps, Sear fish, Croakers, Anchovy etc.

Generally drying is adopted by most of the fish industries in Gujarat State and even in India as preservation method[6] which preserves fish by inactivating enzymes and removing the moisture necessary for bacterial and mould growth[7-9] as contaminating agents cannot survive at low moisture which reduces autolytic activity drastically. The moisture content must be reduced to 15% to prevent mold growth during storage[10]. Refrigeration or artificial dryers are expensive due to requirement of substantial quantity of fuel or electricity to operate which forces to incline towords open fish drying in developing countries. The traditional open sun drying provides cost advantage but suffers from quality parameters due to exposure of product to contamination and insect infestation, along with issues like slow, uncontrolled and non-uniform drying resulting in high losses through spoilage[11]. In solar dryer, contamination from insects, birds, dust, wind and the animals are not found as in case with open sun drying[12] and in addition, the product is protected from rain, insects and dust, and maintain a high quality. Fish, dried in solar dryer also maintains good nutritional qualities and hygien[13]. Use of solar tunnel dryers has been reported for field conditions in about 30 countries under different climatic conditions for drying numerous agricultural commodities ranging from fruits, vegetables, root crops, oil crops, medicinal plants, fish and even meat[14-16]. Compared to sun drying, solar dryers can generate higher air temperatures and lower relative humidity, which is helpful for improving the drying rates and lowering the final moisture content of the drying crops[17].

In this paper, the attempt has been made to design and develop a suitable greenhouse type solar tunnel dryer for drying fish at industrial scale and evaluate the performance for drying selected varieties of local fish.

Material and Methods

Greenhouse Type solar tunnel dryer design: The solar tunnel dryer was designed for drying 250 kg/h fish in batch mode to reduce the moisture content to 16% (wb) from intial moisture of 84% (wb). The detailed design procedure is given is as follows.

Amount of moisture to be removed: The amount of moisture to be removed from a given quantity of wet fish to bring the moisture content to safe storage level at a specified time is calculated using the equation as given below.

$$m_w = \frac{m_p(m_i - m_f)}{100 - m_f} \quad (1)$$

Final or equilibrium relative humidity (ERH): Final or equilibrium relative humidity can be calculated using the sorption isotherm equation as given below[2].

$$a_w = 1 - \exp[-\exp(0.914 + 0.5639 \ln M)] \quad (2)$$

$$a_w = \frac{ERH}{100} \quad (3)$$

Quantity of the heat energy needed to evaporate the water: The total heat energy, E (kJ) required to evaporate water was calculated as follows-

$$E = m'(h_f - h_i)t_d \quad (4)$$

The enthalpy (h) of moist air in J kg^{-1} at temperature T (ºC) can be approximately taken as below[18] –

$$h = 1006.9T + w[2512131.0 + 1552.4T] \quad (5)$$

Average drying rate: Average drying rate, m_{dr}, was determined from the mass of moisture to be removed by solar heat energy and drying time using the following equation-

$$m_{dr} = \frac{m_w}{t_d} \quad (6)$$

The mass of air: The mass of air needed for drying was calculated using equation[19] as follows-

$$m_a = \frac{m_{dr}}{(w_f - w_i)} \quad (7)$$

Collector Area: The collector area (Ac), m^2 for the dryer system can be calculated from the total useful heat energy required to evaporate moisture and the net radiation received by the collector as equation given below-

$$A_c I \eta = E = m_a (h_f - h_i) t_d \quad (8)$$

Therefore, the area of the solar collector is given as-

$$Ac = \frac{E}{I\eta} \quad (9)$$

Generally greenhouse type solar tunnel dryer has hemi cylindrical or semi cylindrical shape and area can be calculated as,

$$A_c = [\pi r L] \quad (10)$$

Volumetric airflow rate of air, V_a: Volumetric airflow rate, V_a was obtained by dividing mass of air, m_a by density of air (1.2 kg m^{-3})

Air vents dimensions: The air vent area was calculated by dividing the volumetric air flow rate by wind speed.

$$A_v = \frac{V_a}{V_w} \quad (11)$$

The length of the air vent, Lv, m, will be equal to the length of the dryer. The width of the air vent can be given by

$$B_v = \frac{A_v}{L_v} \quad (12)$$

Constructional details of solar dryer: The dryer system for fish drying, designed so far had the dimensions as depicted in Table 1. The dryer system was installed at Jose and Bros Fish Industry, a coastal town Veraval in the State of Gujarat. The schematic and actual site installation has been shown in figure-1 and figure-2 respectively.

Table-1
Dimensions of the solar dryer

Parameter	Value
Collector area, A_c	*150.9 m^2*
Dryer length	*21.3 m*
Dryer width	*4.57 m*
Dryer height	*2.12 m*
Vent area, A_v	*0.795 m^2*
Vent length	*4.57 m ~ 4.6 m*
Vent width	*0.17m*
Extra air vent	*West side 4.60 m ×0.74 m* *South side 21.1m × 0.91 m*
Door size	2 m × 1.94 m
No. of air ventilators	5

The designed solar dryer system consisted of important parts as follows: i. A single span arc (GI) used to construct dryer system with a base area of 21.3 m x 4.6 m and maximum ceiling height of 2.2 m. ii. The metallic frame structure of the dryer was consisted of hoops, foundation pipe, end frame and covering material, i.e. single layer 200 µ thick UVS polyethylene sheet. iii. The inlet vent of size 4.6 m x 0.91 m on the west side and 21.3 m x 0.91 m on the south side were provided for air circulation as shown in figure-1. iv. Five numbers of zero energy turbine air ventilators were provided for air exhaust and to enhance the air movement inside the dryer. The capacity of each ventilator was 3313 m^3/h and was placed at the top of the dryer at an equidistance of 4.6 m from each other. v. A door of the size 2 m x 1.94 m was provided on the East end of the dryer for loading and unloading of the material. vi. The orientation of the dryer was kept East- West direction facing toward the south, so that the incident solar radiation collection should be maximized.

Instrumentation and Experimental Procedure: The drying experiments were conducted in the month of April, 2008, started at morning 09:00 h and continued to 17:00 h. The moisture content of thproduct was determined by weight loss method at hourly intervals using a digital weighing balance. Incident solar radiation energy was measured on horizontal surface using Luxmeter. Wind speed and exit air velocity at the chimney outlet were measured by anemometer. Calibrated Ni-Cr thermocouples were used to measure ambient temperature as well as temperature at various locations inside the dryer.

Performance of the solar dryer: The performance of the dryer was evaluated at no load and full load condition. Fresh catch of local varieties of fish Croaker, Anchovy and Ribbon as shown in Figure 3, Figure 4 and Figure 5 respectively, were selected for drying. The fish were kept on the wire /jute net available inside the dryer. The performance of the dryer was statistically evaluated according to Completely Randomized Design (CRD)[20].

Pretreatments of fish: The pretreatments in particular salting used for fish and drying temperature ranges have combined with the fish verities as given in Table 2. The parameters considered for experimental design were Variety (V_1: Croaker, V_2: Anchovy and V_3: Ribbon fish), Pretreatment (S_o: unsalted, S_1: salted) and Temperature (T_1: 40-45 and T_2:45-49°C).

Quality of dried fish: The quality of the dried fish in greenhouse solar tunnel dryer was determined by evaluating protein content, fat content and ash content as well as organoleptic properties like colour, texture and overall acceptability. The protein content in the fish was determined by the micro-Kjeldahl method, taking about 1g of accurately weighed ground sample[21-22]. The fat content in the fish was determined by the Soxhlet extraction method[21-22] using about 5 g of accurately weighed, ground sample and dried at 100±2°C for 16 h for removing the moisture. The ash content was determined by using the muffle furnace at a temperature of 550°C[21]. Organoleptic properties and sensory analysis were determined using sensory evaluation of different organoleptic properties of the dried fish, namely colour, texture and overall acceptability and was carried out by a panel of 10 judges of different age groups on the basis of 9 point hedonic scale. Statistically significant differences among fish species (5% confidence level) were determined.

Results and Discussion

Dryer Performance: The parameters outside the dryer like ambient temperature, relative humidity (RH), and solar radiation ranged between 30°C- 40°C, 29% - 72%, and 450 W/m^2 – 895 W/m^2, respectively, while temperature and relative humidity of the drying air inside the dryer ranged between 36.1°C-51.5°C and 29%-72% as is presented in figure-6 and figure-7 respectively. The maximum drying temperatures attained between 11:00 AM and 2:00 PM, which could raise the maximum temperature inside 5-15°C higher than ambient temperature and remained below 51°C.

Table-2
The fish drying test combinations of the pretreatment, drying temperature and fish varieties

Test	Details
A_1: ($V_1T_1S_1$)	Salt treated Croaker fish dried at temperature 40-45°C
A_2: ($V_1T_2S_1$)	Salt treated Croaker fish dried at temperature 45-49°C
A_3: ($V_1T_1S_0$)	Unsalted Croaker fish dried at temperature 40-45°C
A_4: ($V_1T_2S_0$)	Unsalted Croaker fish dried at temperature 45-49°C
A_5: ($V_2T_1S_1$)	Salt treated Anchovy fish dried at temperature 40-45°C
A_6: ($V_2T_2S_1$)	Salt treated Anchovy fish dried at temperature 45-49°C
A_7: ($V_2T_1S_0$)	Unsalted Anchovy fish dried at temperature 40-45°C
A_8: ($V_2T_2S_0$)	Unsalted Anchovy fish dried at temperature 45-49°C
A_9: ($V_3T_1S_1$)	Salt treated Ribbon Fish dried at temperature 40-45°C
A_{10}: ($V_3T_2S_1$)	Salt treated Ribbon Fish dried at temperature 45-49°C
A_{11}: ($V_3T_1S_0$)	Unsalted Ribbon Fish dried at temperature 40-45°C
A_{12}: ($V_3T_2S_0$)	Unsalted Ribbon Fish dried at temperature 45-49°C

Performance of Fish Drying: Effect of temperature on drying of Salted Fish: The drying behaviour of the salted fish at T_1 (40-45^{0}C) is shown in Figure 8. The initial moisture content of Ribbon, Croaker and Anchovy fish was in the range of 189% (db), 146.35% (db) and 171.7 % respectively. It shows that Anchovy took less time than the other two varieties. The final moisture content reduced to level of 58.73 %, 57.73% and 60.59% for Ribbon, Croaker and Anchovy respectively. It was found that at T_1 (40-45°C), the time taken for drying Ribbon, Croaker and Anchovy was 15 h, 16 h and 9 h respectively. The drying behaviors of salted at T_2 (45-49°C) is shown in figure-9, which shows that initial moisture content of 143.6%, 173.16% and 186.5 % (db) reduced to the level of 48.16%, 56.97% and 51.66, for Croaker, Anchovy and Ribbon respectively. It was revealed that Anchovy took less drying time of 7 h, Ribbon 11h and Croaker 16 h. Almost the same drying trend was found at both temperature ranges.

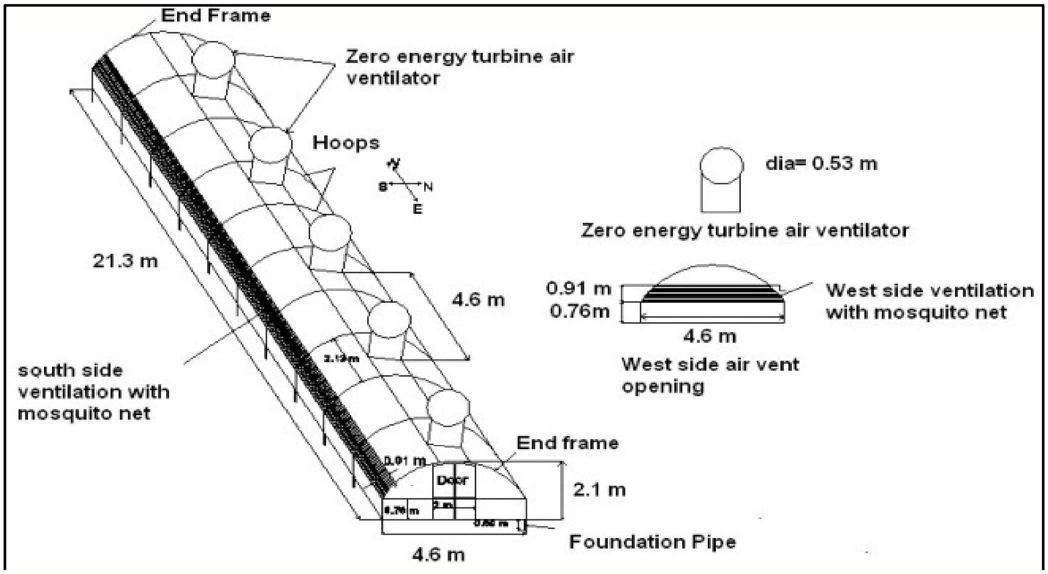

Figure-1
Schematic View of Solar tunnel Dryer

Figure-2
Greenhouse type solar tunnel dryer installation

Figure-3
Raw Croaker

Figure -4
Raw Anchovy

Figure -5
Raw Ribbon

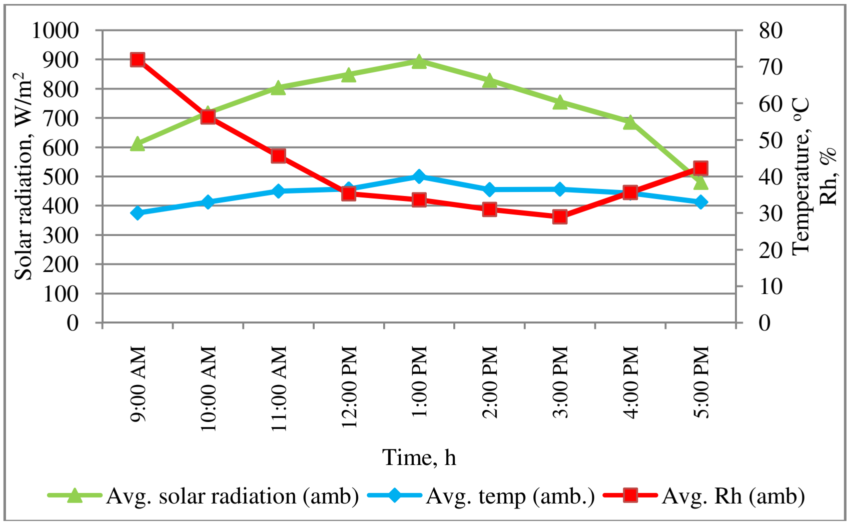

Figure -6
Variation in drying parameters at no load experiment

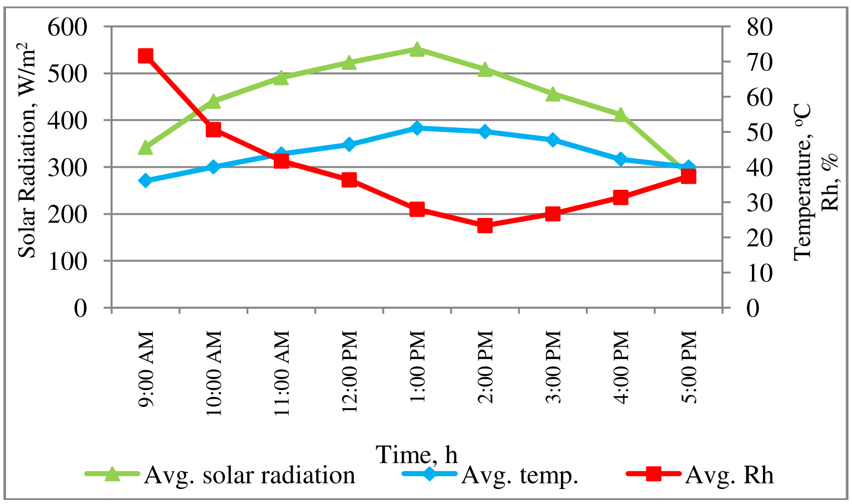

Figure-7
Variation in drying parameters during fish drying experiment

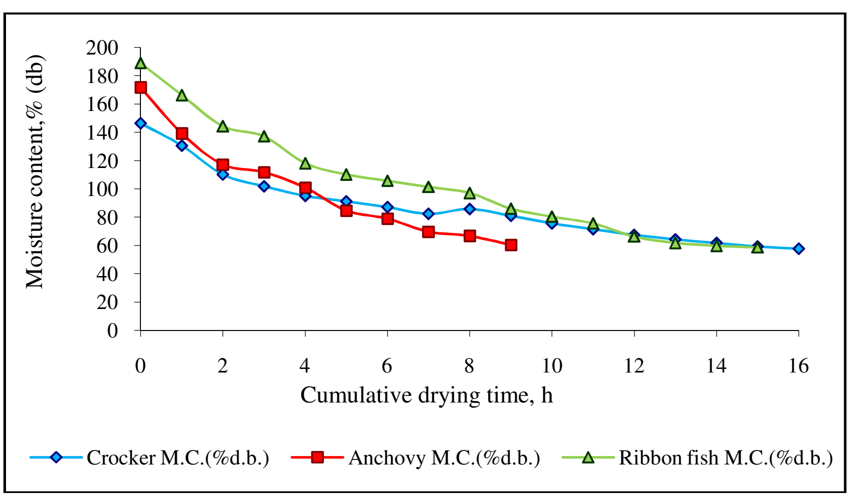

Figure-8
Drying behaviour of salt treated fish at T_1 (40-45 ^{O}C)

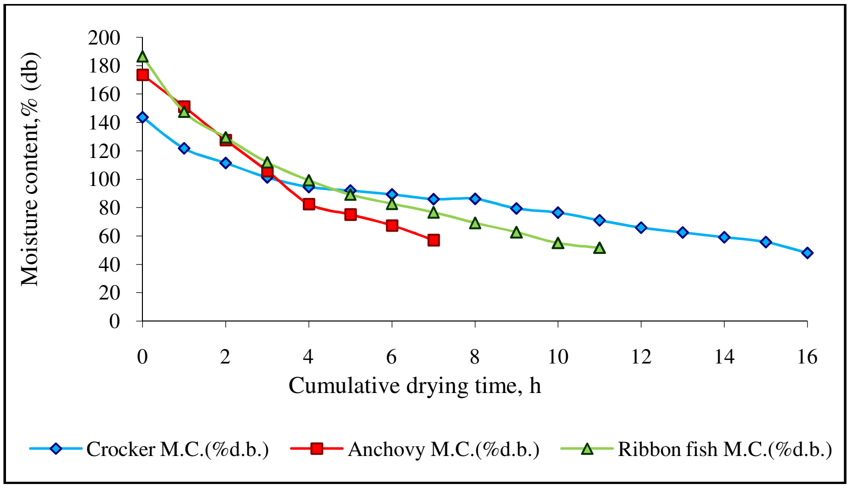

Figure-9
Drying behaviour of salt treated at T_2 (45-49 ^OC)

Effect of temperature on drying unsalted fish: The drying trend of unsalted Croaker, Anchovy and Ribbon fish at T_1 (40-45°C) is shown in Figure10. Anchovy fish had highest initial moisture content of 296.05 % (db) followed by Croaker (266.95%) and Anchovy (287.5%). Ribbon took 28 h, Anchovy 16 h and almost similar for Croaker (26 h) to reach final moisture content of 19.33%, 22.84% and 20.93% respectively. The drying trend of unsalted fish at T_2 (45-49 °C) for Ribbon, Croaker and Anchovy is shown in figure-11. Initial moisture content of Croaker, Anchovy and Ribbon was in the range of 256.45%, 287.45% and 292.1 % respectively, which reduced to 17.61%, 14.02% and 19.475 respectively. It took about of 13 h for Anchovy and almost 21 h for both Ribbon and Croaker for drying. From the study it was also observed that in salt treated fish took less time for drying than unsalted fish.

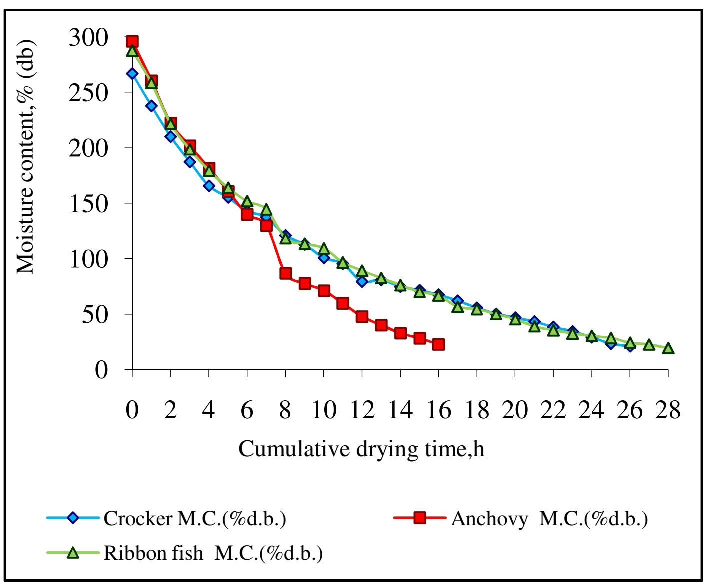

Figure-10
Drying behaviour of unsalted at T_1 (40-45 ^OC)

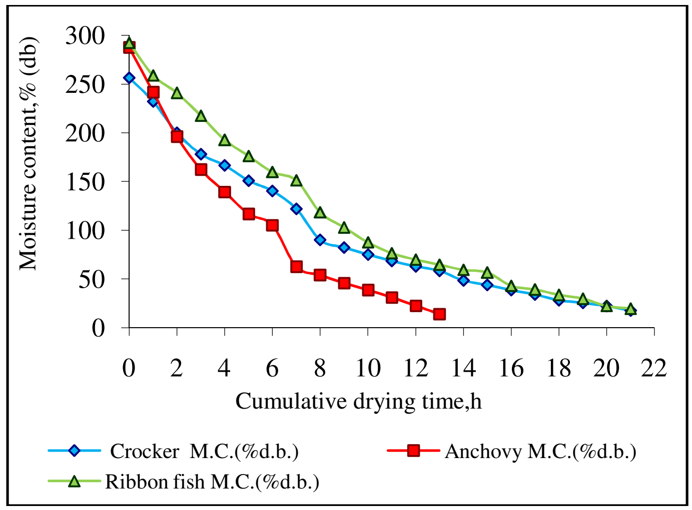

Figure-11
Drying behaviour of unsalted at T_2 (45-49 ^OC)

Overall effect of variety (V), temperature (T) and pre-treatment (S) on fish drying: The effect of variety, temperature, salting and without salting conditions analysed statistically and depicted in table-4. There was no significant difference found in the final moisture content of all the three varieties used in drying experiment as the final moisture content attended was almost at the same level. The two drying temperature conditions, i.e. T_1(40-45) and T_2(45-49 figure) showed a significant difference in final moisture content as rate of moisture removal depends on the surrounding temperature in which the drying process takes place. The significant reduction in drying time for salt treated fish and unsalted fish was observed as shown in drying curves in figure-8 to figure-11. Final moisture content in fish was higher (26.45 %) for T_1 than that of T_2 (23.59 %). The significant difference between the final moisture content of salted (S_1) and unsalted fish (S_0) was observed whereas the salted fish moisture content was higher

(35.20 % (wb)) than unsalted fish moisture content (14.84 % (wb)) which shows that salt treated fish had better response in drying. Two temperature conditions T_1 (40-45°C) and T_2 (45-49°C) differed significantly in drying time for all three varieties. T_1 required higher drying time as compared to T_2.

For different varieties, significant difference was found in protein content. Variety V_3 (Ribbon) gave significantly highest protein content of 52.51%, followed by V_1 (44.07 %) and V_2 (38.37 %). For different temperature ranges, no much difference was found in protein content. It was found 44.24% and 46.20% for T_1 and T_2 range respectively. For different pretreatment of S_1: salting and S_0: unsalting, highest protein content of 51.32 % was found for S_0 while for S_1, it was 39.31%. For different varieties, the fat content was found 6.54%, 7.08% and 4.63 % for variety V_1 (Croaker), V_2 (Anchovy) and V_3 (Ribbon) respectively. For different temperature ranges, the fat content was 5.91% and 6.21% for T_1 (40-45 °C) and T_2 (45-49 °C) respectively. For different pretreatment of S_1: salting and S_0: unsalting, highest fat content of 7.34 % was found for S_0 while for S_1 it was 4.82% respectively. Ash content for V_1 (Croaker) and V_2 (Anchovy) was almost in the same range, i.e. little more than 16% while, it was found highest for V_2 (Anchovy). The ash content for both temperature ranges of T_1 (40-45 °C) and T_2 (45-49 °C) was found in the same range of 19.1 to 19.78 %. There was a significant difference in ash content for both pretreatment of S_1: salting and S_0: unsalting. The highest ash content of 23.10 % was found for S_0 while for S_1 it was 15.78%. Overall the parameters measured to access the quality of the fish showed a varying effect on protein and fat content due to drying temperature, whereas the pretreatment showed significant reduction in protein content. The increase in drying temperature irrespective of the pre-treatment showed that the increase of drying temperature reduces the fish quality because it accelerates the biochemical and microbiological decomposition of fish, especially salted fish[23].

Organoleptic evaluation of solar dried fish: The data for colour, texture and overall acceptability analysed statistically using CRD method as depicted in table-3 showed that the variety V_1 received significantly highest colour score (7.025) followed by variety V_2 (6.975) and variety V_3 (6.325). There was no significant effect of temperature and salting on colour. It was observed that treatment A_4 had highest mean score (7.5) i.e. dried fish resulted from treatment A_4 good in colour. Treatment A_9 and A_{12} found resulted in poor color. Variety V_2 received significantly scored highest of 7.10 followed by variety V_1 (6.75) and variety V_3 (6.47). No significant difference found for temperature and salting on texture of fish. Treatment A_5 had highest mean score of 7.6 which shows fish resulted from treatment A_5 had good texture while treatments A_2, A_9 and A_{12} were found poor in texture.

Conclusion

Fish is very sensitive to the temperature and preferred low level temperature drying in the range of 40 45°C to 45°C. Drying properties depends on variety, initial moisture content, pretreatment (salting or unsalting) and temperature range. Two temperature conditions showed a significant difference in final moisture content of the fish. Good quality salt treated fish were obtained in T_1 range, whereas T_2 range was found best for unsalted fish in terms of quality and drying time. Similarly, the nutritional components change according to drying temperature as well as pre-treatment used.

Table-3
Effect of different factors on organoleptic characters of fish

Treatment	Mean		
	Colour	Texture	Overall Acceptability
Variety (V)			
V_1(Croaker)	7.025	6.75	7.00
V_2 (Anchovy)	6.975	7.10	7.17
V_3(Ribbon fish)	6.325	6.47	6.60
SE_m	0.12	0.130	0.130
CD at 5% level	0.364	0.366	0.367
Temperature(T)			
T_1 (40-45^{0}C)	6.783	6.86	6.983
T_2 (45-49^{0}C)	6.767	6.68	6.867
SE_m	0.105	0.106	0.106
CD at 5% level	NS	NS	NS
Salting (S)			
Without salting (S_0)	6.85	6.70	6.90
With salting (S_1)	6.70	6.85	6.95
SE_m	0.105	0.106	0.106
CD at 5% level	NS	NS	NS
Significant interactions			
V*T*S			
SE_m	0.259	0.260	0.261
CD at 5 % level	0.728	0.732	0.735

NS-non significant

Abbreviation:

A_c	:	Collector area, m^2
A_v	:	Area of the air vent, m^2
a_w	:	Water activity, decimal
B_v	:	Width of air vent, m
CD	:	Critical Differences
CRD	:	Completely Randomized Design
db	:	Dry basis, %
E	:	Total useful energy received by the drying air, kJ
ERH	:	Equilibrium relative humidity, %
h	:	Enthalpy of moist air, J/kg
h_f and h_i	:	Final and initial enthalpy of drying and ambient air, respectively, kJ/kg dry air.
I	:	Total global radiation on the horizontal surface during the drying period, kJ/ m^2
L	:	Length of dryer, m
L_v	:	Length of air vent, m
M	:	Final moisture content of product on dry basis.
m′	:	Mass flow rate of air, kg/hr
m_{dr}	:	Average drying rate, kg/hr
m_f	:	Final moisture content of the fish, % (wet basis)
m_i	:	Initial moisture content of the fish, % (wet basis)
m_p	:	Initial mass of the product to be dried, kg
m_w	:	Amount of moisture to be removed, kg
r	:	Radius of semi cylinder, m
SE_m	:	Standard error of mean
T	:	Temperature, ^oC
t_d	:	Drying time, hrs
UVS	:	Ultra violet stabilized
Va	:	Volumetric air flow rate, m^3/s
V_w	:	Wind speed, m/s.
wb	:	Wet basis, %
w_f and w_i	:	Final and initial humidity ratio, respectively, kg of water/kg dry air.
η	:	Collector efficiency

References

1. Jain D., Determination of convective heat and mass transfer coefficients for solar drying of fish, *Biosyst. Eng.,* **94(3),** 429–435 (**2006**)

2. Ayyappan S., Diwan A.D., Fish for food security—an opportunity, *Indian Farming,* **53(7),** 47–51 **(2003)**

3. Annual Report, Department of animal husbandry, dairying and fisheries. Ministry of agriculture, Government of India, New Delhi (**2012-13)**

4. Govindan T.K., Fish Processing Technology. Oxford and IBH Publishing Co. Pvt. Ltd., India **(1985)**

5. Annual Report., Central marine Fisheries Research institute. Indian Council of Agricultural Research, New Delhi (**2013-14)**

6. Anonymous, Deep sea fishing: Towards diversified operations, The Hindu, January 6 **(2003)**

7. Bellagha S., Amami E., Farhat A. and Kechaou N., Drying kinetics and characteristic drying curve of lightly salted Sardine (Sardinella aurita), *Drying Technol.,* **20(7)**, 1527–1538 (**2002)**

8. Bala B.K. and Mondol M.R.A., Experimental investigation on solar drying of fish using solar tunnel dryer drying technology, **19(2)** 427-436 **(2001)**

9. Duan Z.H., Jiang L.N., Wang J.L., Yu X.Y. and Wang T., Drying and quality characteristics of tilapia fish fillets dried with hot air-microwave heating, *Food Bioprod. Process.,* (**2010**)

10. Prabhu P.V., Balachadran K.K., Drying of fish. Food drying; Proceedings of Workshop held at Edmonton, Alberta, July 6-9**(1982)**

11. Carpio E.V., Drying of fish in Philippines in Food Drying, Proceedings of workshop held at Edmonton, Alberta, July 6-9 **(1982)**

12. Bhor P.P., Khandetod Y.P., Mohod A.G. and Sengar S.H., Performance study of solar tunnel dryer for drying of fish variety *dhoma, International Journal of Agricultural Engineering,* **2(2),** 222-227 **(2010)**

13. Patterson J. and Govindan R., Qualities of commercially and experimentally sun dried fin fish, Scomberoides tol, *African Journal of Food Science,* **3(10)**, 299-302**(2009)**

14. Emad A Almuhanna., Utilization of a solar greenhouse as a solar dryer for drying dates under the climatic conditions of the eastern province of Saudi Arabia, *Journal of Agricultural Science,* **4(3) (2012)**

15. Lutz K., Muhlbauer W., Muller J. and Reisinge G. Development of multi- purpose solar crop dryer for arid zones, *Solar and Wind Technology,* **4(4)**, 417-424 **(1987)**

16. Esper A., Hensel O. and Muhlbauer W., PV-Driven Solar Tunnel Dryer, Agricultural Engineering Conference, Bangkok, Dec. 6-9**(1994)**

17. Muhlbauer W., Present status of solar crop drying, *Energy Agriculture*, **5**, 121-137**(1986)**

18. Hernandez J.A., Pavon G. and Garcia M.A., Analytical solution of mass transfer equation considering shrinkage for modeling food-drying kinetics, *Journal of Food Engineering,* **45(1),** 1-10 **(2000)**

19. Sodha M.S., Bansal N.K., Kumar K., Bansal P.K. and Malik M.S.S., Solar Crop Drying, Volume II. CRC Press, Boca Raton, Florida, **(1987)**

20. Rangaswamy R., A Text Book of Agricultural Statistics. New Age International (P) Limited, New Delhi, 139-141 **(2002)**

21. AOAC., Association of Official Analytical Chemist, Official Method of Analysis, **(1980)**

22. Ranganna S., Handbook of analysis and quality control for fruit and vegrtable products, Tata McGraw-Hill education, (**1986)**

23. Kilic A., Low temperature and highvelocity (LTHV) application in drying: Characteristics and effects on fish quality, *Journal of Food Engineering*, **91,** 173-182 **(2009)**